A High-Temperature Superconducting Duplexer for Cellular Base-Station Applications

Jia-Sheng Hong, *Member, IEEE*, Michael J. Lancaster, *Member, IEEE*, Robert B. Greed, Dieter Jedamzik, Jean-Claude Mage, *Associate Member, IEEE*, and Heinz J. Chaloupka, *Senior Member, IEEE*

***Abstract*—This paper presents a recent investigation of a high-temperature superconducting (HTS) duplexer for cellular base-station applications. The duplexer consists of two HTS hybrids and two HTS bandstop filters. The principle and design of the duplexer are described. The components of the duplexer were fabricated individually using double-sided $YBa_2Cu_3O_7$ (YBCO) thin films on $LaAlO_3$ (LAO) substrates. The substrate size for each of the hybrids was 0.5 × 22.5 × 15.5 mm, while each of the bandstop filters had a substrate size of 0.5 × 13× 38 mm. Experiments were performed both with a test housing in a liquid-nitrogen cooler at a temperature of 80 K and in an encapsulated RF connector ring in a vacuum cooler at 55 K. The measured insertion loss was less than 0.3 dB both from the antenna to receiver ports over a receive band of 1770–1785 MHz and from the transmitter to antenna ports over a transmit band of 1805–1880 MHz. The isolation between the transmitter and receiver was measured to be greater than 35 dB. Good measured results were also obtained for the encapsulated duplexer with the maximum insertion loss of 1.15 dB, the additional loss being due to the microstrip feed lines across the vacuum space, and the minimum isolation of about 30 dB.**

***Index Terms*—Cellular base-station, HTS filters, mobile communication, superconducting duplexer.**

I. INTRODUCTION

PERSONAL mobile communication requirements are placing increasing demands on existing technologies. High-temperature superconductivity (HTS) is a new technology, which offers enhanced performance together with the possibilities for novel miniature architectures and functions [1]–[6]. Present mobile (cellular) communications systems are narrow-band voice systems, and advanced voice-coding and cell-splitting techniques make it possible to provide a large number of speech channels even in congested urban areas. Although existing semiconductor technology can cope with the present growth of these channels, there is ample room for improvements in the areas of the size reduction of subsystems, the power consumption of handheld terminals, and the sensitivity and channel separation in base-stations. These improvements may provide the opportunity for a real commercial breakthrough for HTS devices.

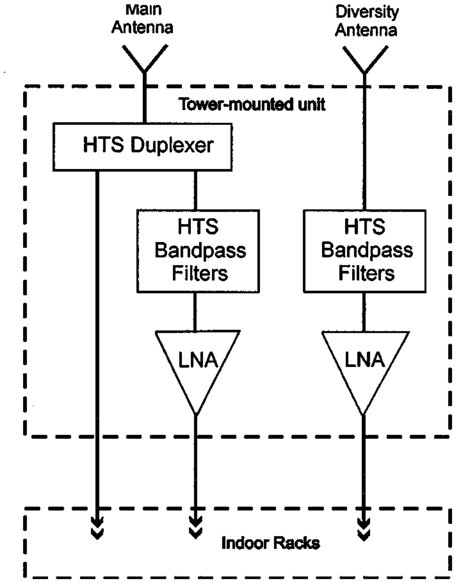


Fig. 1. Typical base-station sector using HTS subsystem.

In this paper, we report on the recent investigation of the design, fabrication, and performance of a high-temperature superconducting duplexer. This is one of the components necessary for constructing a tower-mounted transceiver for cellular base-station application. A typical system is shown in Fig. 1. The HTS-based transceiver is for the DCS1800 standard, which covers a receive (Rx) band from 1710 to 1785 MHz, and a transmit (Tx) band from 1805 to 1880 MHz. The function of the duplexer is twofold: 1) to route the received signal from the antenna to the receiver channel filter that covers a 15-MHz sub-band of the Rx band and 2) to route the high-power Tx signal from the Tx filter to the antenna. In the latter case, this must be accomplished without any significant amount of power from the Tx signal being incident upon the Rx filter (good isolation between Tx and Rx). The result is that one antenna can be used for both Tx and Rx functions. The duplexer described is developed within a European consortium sponsored by the European Commission. It involves a number of companies (Marconi, Grat Baddow, U.K., Thomson CSF, Orsay, France, and Leybold, Koln, Germany) and two universities (University of Birmingham, Birmingham, U.K., and University of Wuppertal, Wuppertal, Germany). The project acronym is SUCOMS, which

---

Manuscript received March 23, 1999. The work was supported by the European Commission under the Advanced Communications Technologies and Services Program.

J.-S. Hong and M. J. Lancaster are with the School of Electronic and Electrical Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, U.K.

R. B. Greed and D. Jedamzik are with the Marconi Research Centre, Essex CM2 8HN, U.K.

J.-C. Mage is with Thomson-CSF/CNRS, Domaine de Corbeville F-91404 Orsay, France.

H. J. Chaloupka is with the Department of Electrical Engineering, Bergische University-GHS Wuppertal, D-42097 Wuppertal, Germany.

Publisher Item Identifier S 0018-9480(00)06535-2.

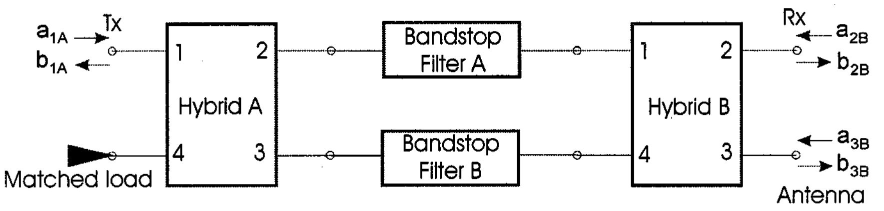


Fig. 2. Schematic diagram of the proposed duplexer

stands for "superconducting systems for communications," and it is funded through the Advanced Communications Technologies and Services (ACTS) Program. More details of the project can be found in [7], [8].

II. DUPLEXER PRINCIPLE

The proposed duplexer consists of two −3-dB hybrids and two bandstop filters, connected as in Fig. 2. Assume that port 1 of the hybrid *A* is the Tx port, ports 2 and 3 of the hybrid *B* are then the Rx and antenna ports, respectively. The operation principle of the duplexer may be described as follows.

For our purpose, let us assume that the hybrids are ideal, which are represented by a scattering matrix

$$[S]_H = \begin{bmatrix} 0 & -j1/\sqrt{2} & -1/\sqrt{2} & 0 \\ -j1/\sqrt{2} & 0 & 0 & -1/\sqrt{2} \\ -1/\sqrt{2} & 0 & 0 & -j1/\sqrt{2} \\ 0 & -1/\sqrt{2} & -j1/\sqrt{2} & 0 \end{bmatrix}. \quad (1)$$

Consider the hybrid *B* on the right-hand side of Fig. 2. Its ports 1 and 4 can be looked as terminated by the two loads with reflection coefficients of Γ_1 and Γ_4, which, as a matter of fact, are the reflection coefficients of the two bandstop filters, respectively. It can be shown that the resultant two-port network is described by

$$\begin{bmatrix} b_{2B} \\ b_{3B} \end{bmatrix} = \begin{bmatrix} \frac{1}{2}(\Gamma_4 - \Gamma_1) & \frac{j}{2}(\Gamma_1 + \Gamma_4) \\ \frac{j}{2}(\Gamma_1 + \Gamma_4) & \frac{1}{2}(\Gamma_1 - \Gamma_4) \end{bmatrix} \begin{bmatrix} a_{2B} \\ a_{3B} \end{bmatrix} \quad (2)$$

where a and b denote the incident and reflected wave variables. If $\Gamma_1 = \Gamma_4 = \Gamma$, the transmission from the antenna port to the receiver port is given by

$$S_{\text{Antenna-Rx}} = \frac{b_{2B}}{a_{3B}} = j\Gamma. \quad (3)$$

It is now clear that if $|\Gamma| = 1$, the received signal at the antenna port will be diverted into the receiver port without any loss. The first condition for $\Gamma_1 = \Gamma_4$ requires two identical bandstop filters, while the second condition for $|\Gamma| = 1$ requires the bandstop filters to have not only high rejection at the Rx band frequencies, but also very low loss in the reflected signal. This necessities the use of a superconductor because of its low conductor loss, particularly if the circuits are to be miniaturized.

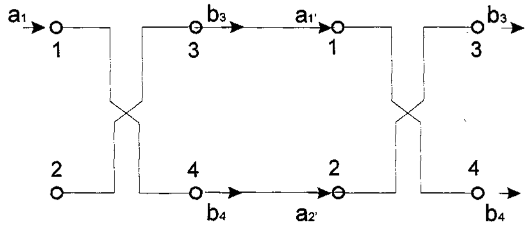


Fig. 3. Tandem coupler formed by cascading two ideal directional couplers

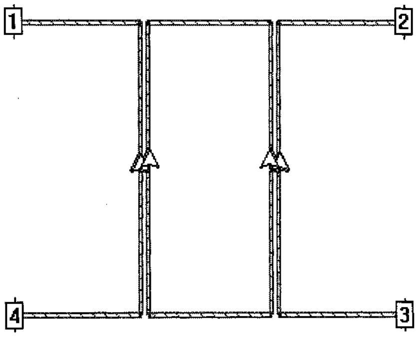


Fig. 4. Layout of HTS hybrid using tandem couplers on an LAO substrate.

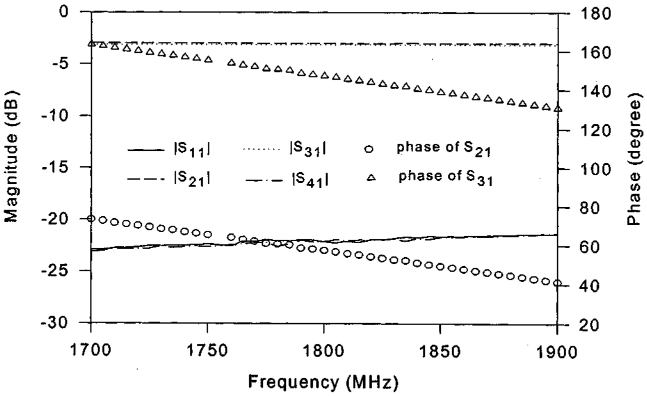


Fig. 5. Full-wave simulation of the HTS hybrid on an LAO substrate.

Next, let us assume that the bandstop filters have no attenuation at the Tx band so that they may be treated as the two ideal phase shifters with a phase constant of θ. If a transmitting signal represented by a_{1A} inputs at the transmitter port, it can be shown that

$$S_{\text{Tx-Rx}} = \frac{b_{2B}}{a_{1A}} = (S_{21} \cdot S_{21} + S_{24} \cdot S_{31}) \cdot e^{-j\theta}$$

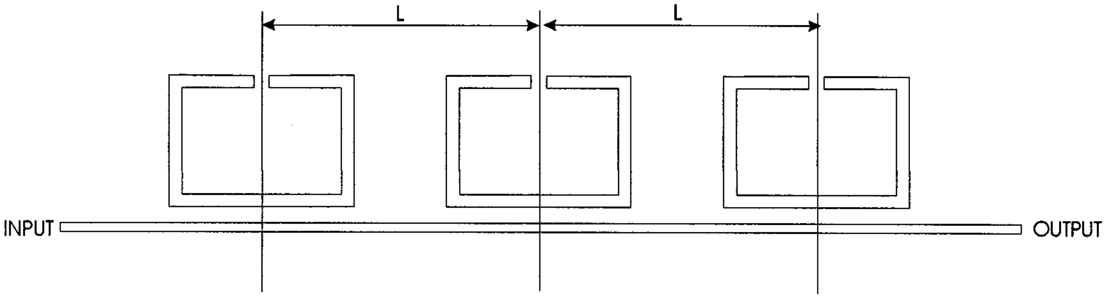


Fig. 6. Distributed parameter bandstop filter using three open-loop resonators.

$$S_{\text{Tx-Antenna}} = \frac{b_{3B}}{a_{1A}} = (S_{31} \cdot S_{21} + S_{34} \cdot S_{31}) \cdot e^{-j\theta}. \tag{4}$$

Substituting the S-parameters of the ideal hybrid from (1) to (4) gives

$$S_{\text{Tx-Rx}} = 0 \quad S_{\text{Tx-Antenna}} = e^{-j(\theta - \pi/2)}. \tag{5}$$

Therefore, the signal from the transmitter port is totally diverted to the antenna port, and there is an ideal isolation between the transmitter and receiver ports. One might notice that, to arrive at (5), the phase θ is not necessary to be a constant over the entire Tx band.

III. DUPLEXER DESIGN

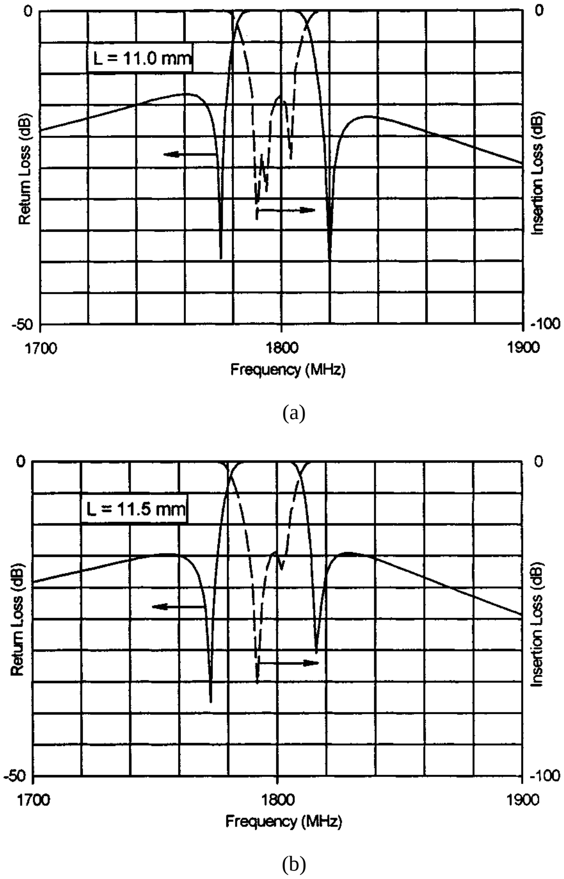
As a starting point for the design, an LAO substrate with a relative dielectric constant of 23.4 was chosen in order to reduce the size of the duplexer module for encapsulation with the other components in the tower-mounted unit of Fig. 1. In considering the required overall power handling (12 W) of the Tx channel, it was also decided to design and fabricate HTS hybrids. Since there are no resonant elements at the Tx band, the power-handling capability of the transmission line is more than adequate. The design of the HTS hybrid and bandstop filter are described below.

A. Hybrids

The simplest -3-dB hybrid would be the branch-line coupler [9]–[11]. However, it provides very little design margin due to its limited bandwidth. Therefore, it was chosen to use tandem couplers [12]. A tandem arrangement of two coupled line directional couplers in Fig. 4 results in a wider bandwidth, which can improve the overall performance of the duplexer. Besides, the tandem coupler has a smaller size. The tandem connection entails two line crossings, which may be realized using bond-wire bridges. The operation principle of the tandem coupler is described as referring to Fig. 3, where a and b represent the incident and reflected wave variables, respectively. It can be shown that the transmissions from port 1 to ports 3′ and 4′ are given by

$$S_{3'1} = \frac{b_{3'}}{a_1} = t^2 - c^2 \quad S_{4'1} = \frac{b_{4'}}{a_1} = j2ct \tag{6}$$

where c and t denote the scaled coupling and transmission coefficients. One can notice that there is always 90° phase difference



(a)

(b)

Fig. 7. Full-wave simulated frequency response of the HTS bandstop filter on LAO substrate. (a) $L = 11.0$ mm. (b) $L = 11.5$ mm.

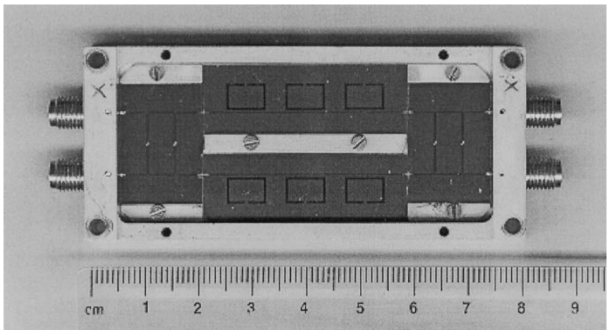
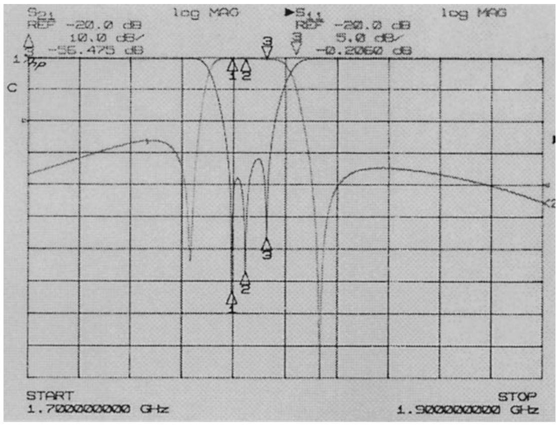
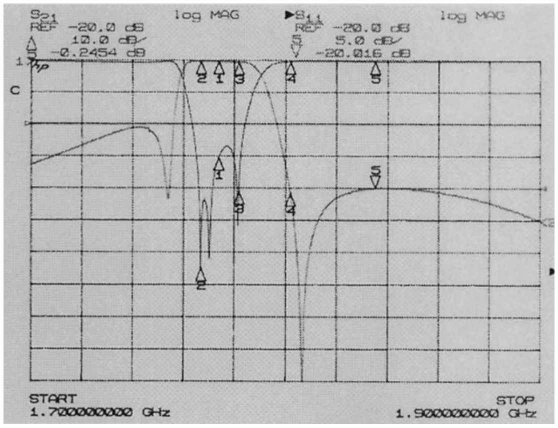


Fig. 8. Fabricated HTS duplexer in a test housing.



(a)



(b)

Fig. 9. Measured performance of the HTS bandstop filter. (a) Before tuning. (b) After tuning.

between the two outputs regardless of their magnitudes. The equal magnitude of the two outputs can be achieved by using the condition

$$t^2 - c^2 = 2ct = \frac{1}{\sqrt{2}}. \qquad (7)$$

Solving the equations yields

$$c = 0.3827 = -8.34 \text{ dB}. \qquad (8)$$

Hence, what is needed for a -3-dB tandem coupler is to design a pair of -8.34-dB directional couplers. For quarter-wavelength coupled microstrip line realization, the design equations are

$$Z_{0e} = Z_0\sqrt{\frac{1+c}{1-c}} \quad Z_{0o} = Z_0\sqrt{\frac{1-c}{1+c}} \qquad (9)$$

where Z_{0e} and Z_{0o} are the even- and odd-mode impedance. Z_0 is the matching impedance at the ports, and is equal to 50 Ω in our design. The design of the HTS hybrid on an LAO substrate was done with the aid of a full-wave electromagnetic (EM) simulator [13]. Fig. 4 depicts the layout of the hybrid for the full-wave EM simulation, where the arrows indicate the line crossings. The simulated frequency response is shown in Fig. 5.

TABLE I
SUMMARY OF MEASURED PERFORMANCE OF THE DUPLEXER IN THE TEST HOUSING ($T = 80$ K)

FREQUENCY	1770 - 1785 MHz (Rx-Band)	1805 - 1880 MHz (Tx-Band)
Antenna-Receiver Loss	< 0.3 dB	
Transmitter-Antenna Loss		< 0.3 dB
Transmitter-Receiver Isolation	> 43 dB	> 35 dB
Antenna Port Return Loss	> 27 dB	> 26 dB
Receiver Port Return Loss	> 25 dB	
Transmitter Port Return Loss		> 28 dB

TABLE II
SUMMARY OF MEASURED PERFORMANCE OF A DUPLEXER IN THE RF CONNECTOR RING (T=55 K)

FREQUENCY	1770 - 1785 MHz (Rx-Band)	1805 - 1880 MHz (Tx-Band)
Antenna-Receiver Loss	< 1.13 dB	
Transmitter-Antenna Loss		< 1.15 dB
Transmitter-Receiver Isolation	> 35.0 dB	> 29.9 dB
Antenna Port Return Loss	> 15.0 dB	> 15.0 dB
Receiver Port Return Loss	> 14.4 dB	
Transmitter Port Return Loss		> 15.0 dB

B. Bandstop Filters

The specifications for the required bandstop filters are as follows:

stopband frequencies	1770–1785 MHz;
minimum stopband attenuation	20 dB;
passband frequencies	1805–1880 MHz;
passband ripple	0.1 dB.

These specifications can be met with a three-pole Chebyshev bandstop filter. Its low-pass prototype has the element values

$$g_0 = g_4 = 1.0 \quad g_1 = g_3 = 1.0315 \quad g_2 = 1.1474. \qquad (10)$$

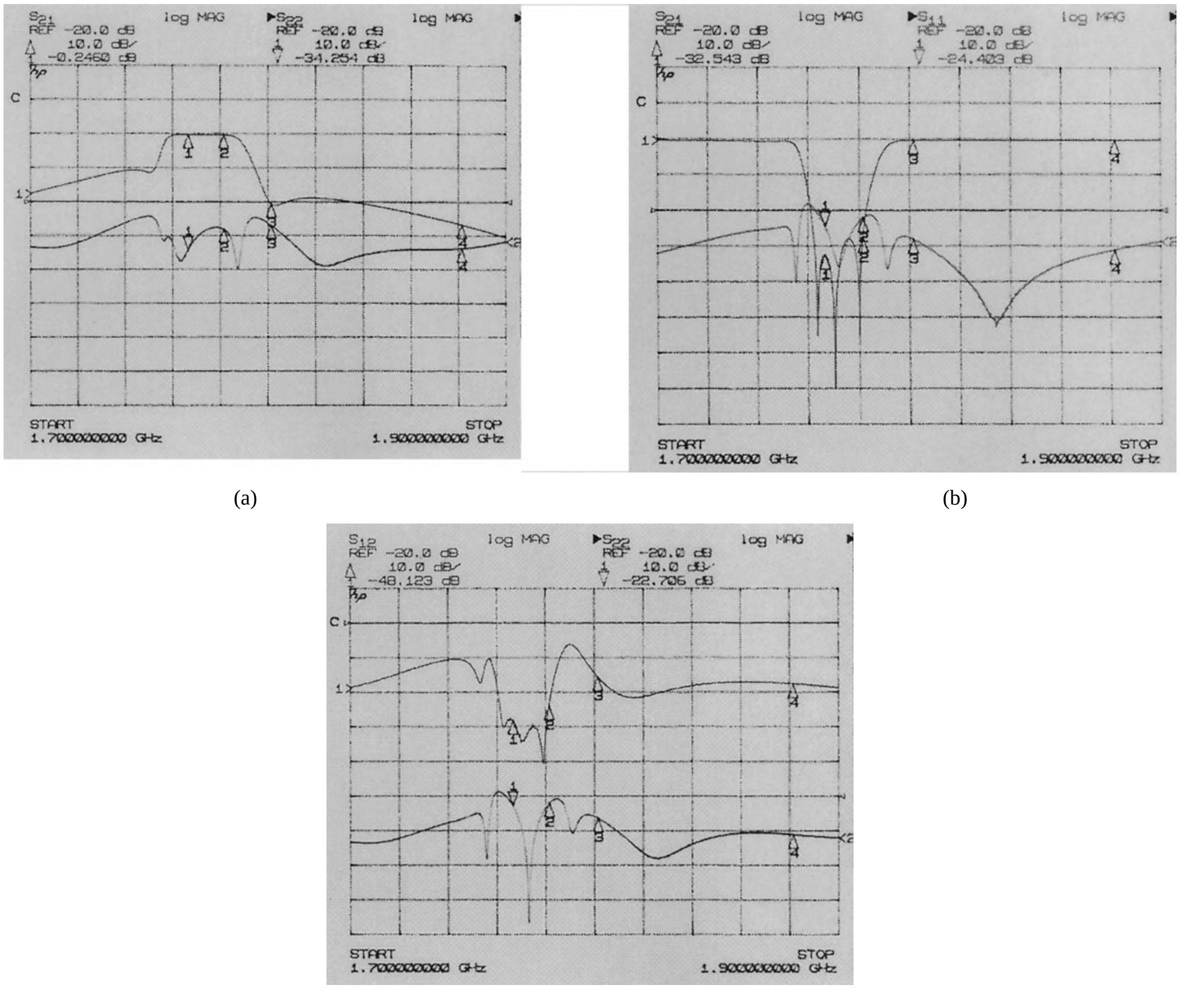
The design of the distributed parameter bandstop filter started with the normalized reactance slope parameters [14]

$$x_1 = x_3 = \frac{f_0}{g_0 \cdot g_1 \cdot \Delta f_{3\text{dB}}} \quad x_2 = \frac{g_0 \cdot f_0}{g_2 \cdot \Delta f_{3\text{dB}}} \qquad (11)$$

where f_0 is the center frequency of the bandstop filter and $\Delta f_{3\text{dB}}$ is the 3-dB rejection bandwidth. The 3-dB bandwidth of each resonator connected across a uniform transmission line of normalized characteristic impedance equal to $z_0 = g_0 = g_4$, which is terminated at both ends, is then given by

$$\Delta f_1 = \Delta f_3 = \frac{f_0}{2x_1} \quad \Delta f_2 = \frac{f_0}{2x_2}. \qquad (12)$$

We used three open-loop resonators, which are coupled to a 50-Ω microstrip line, as shown in Fig. 6. The coupling spacing



(a) (b)

(c)

Fig. 10. Measured performance of the HTS duplexer in the test housing at $T = 80$K. (a) Antenna–receiver. (b) Transmitter–antenna. (c) Transmitter–receiver.

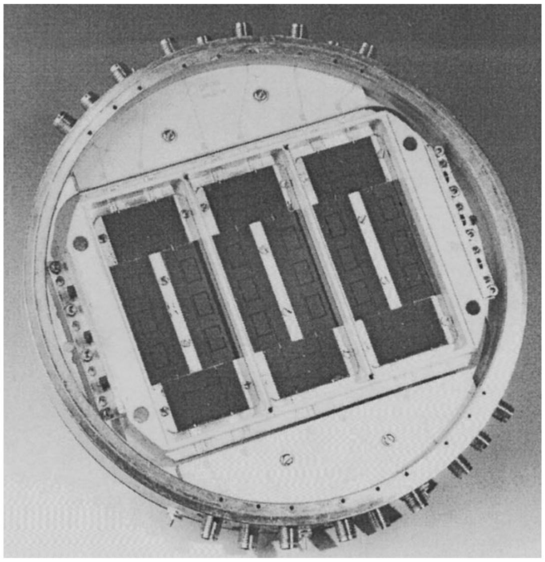


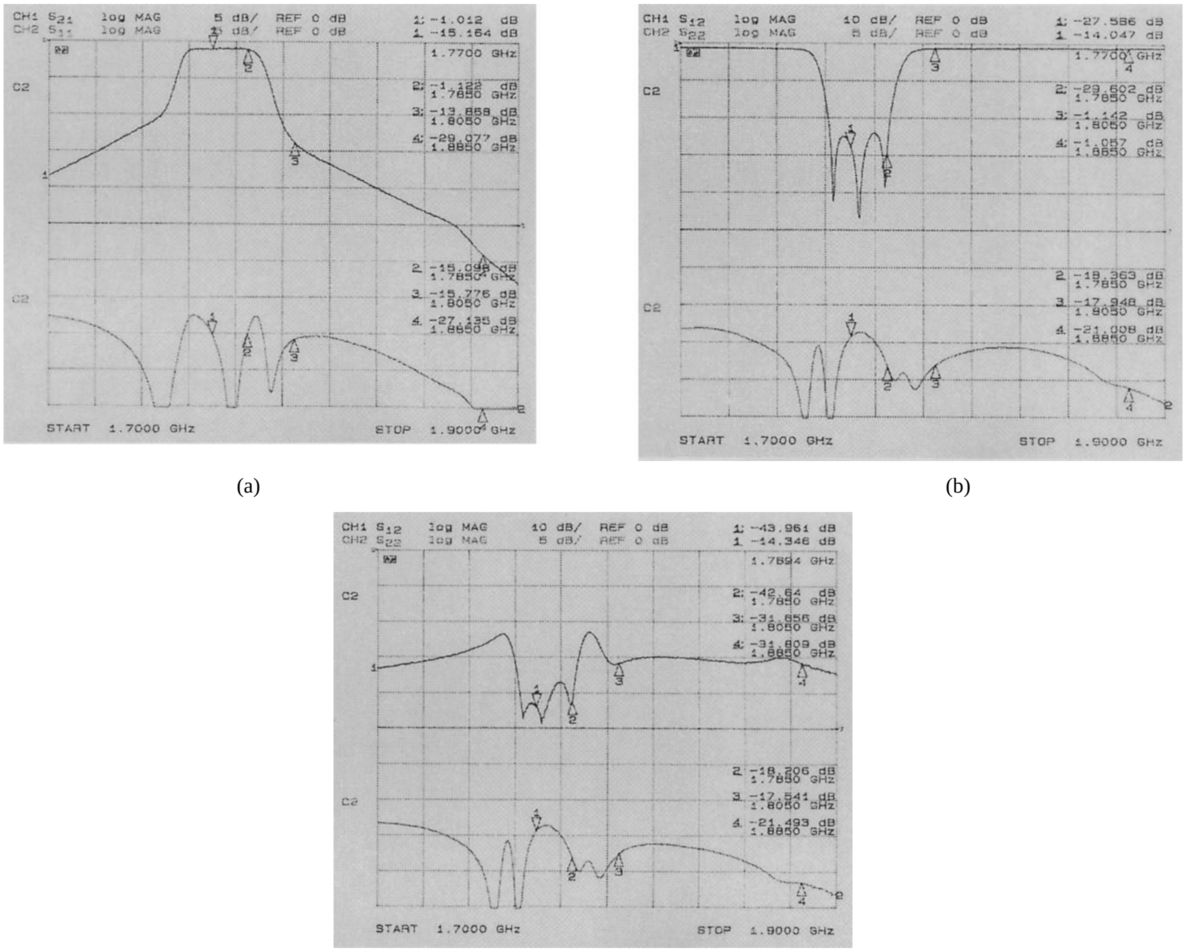
Fig. 11. Three similarly fabricated HTS duplexers assembled in an RF connector ring for encapsulation.

for each resonator to the 50-Ω line was determined using the full-wave simulation [13] to obtain the required 3-dB bandwidth, as given in (12). The separation between the resonators as denoted by L was approximately a quarter-wavelength. The full-wave simulation of the whole filter response is depicted in Fig. 7(a). It should be remarked that the return loss of the filter shows an asymmetric frequency response. Although a more symmetric response could be achieved by slightly increasing the inter-resonator separation L, as shown in Fig. 7(b), the asymmetric one would rather be desirable in regard of a lower return loss at the Tx band.

IV. EXPERIMENTS WITH A TEST HOUSING

Shown in Fig. 8 is the photograph of the fabricated HTS duplexer in a test housing. The superconducting hybrids and bandstop filters were fabricated using a double-sided YBCO thin-film HTS material on 0.5-mm-thick LAO substrates. As can be seen, the two hybrids and the two bandstop filters are on the separated substrates. Each of the hybrids had a circuit size of 15.5 × 22.5 mm, while the size of each bandstop filter was 38 × 13 mm. They were mounted on gold-plated titanium carriers using conductive silver epoxy, and then the carriers were fixed into the test housing by screws. Bond wires were used for interconnections.

To verify the EM design, one of the HTS bandstop filters was tested by replacing the hybrids with the 50-Ω transmission



(a) (b) (c)

Fig. 12. Measured performance of an HTS duplexer in the encapsulated RF connector ring at a temperature of $T = 55$K. (a) Antenna–receiver. (b) Transmitter–antenna. (c) Transmitter–receiver.

lines before testing the whole duplexer. The hybrids were also tested by replacing the bandstop filters by similar 50-Ω lines. The bandstop filter was measured at a temperature of 80 K in an open-bath liquid-nitrogen cooler. Fig. 9 shows the measured frequency responses before and after tuning. Without any tuning, the measured filter performance showed a good agreement with the simulated response in Fig. 8(a), except for the center frequency. The tuning was aimed to shift the center frequency and to keep the return loss down to -20 dB over the entire Tx band. Over the rejection band, the rejection (S_{21}) was greater than 25 dB, while the loss of the rejected signals (S_{11}) was less than 0.3 dB, which included the I/O contact loss. The asymmetrical frequency response of S_{11} also achieved keeping the low return loss over the Tx band.

The test of the HTS duplexer in the test housing was carried out using the same experimental setup. Fig. 10 shows the measured performance of the HTS duplexer at 80 K after tuning. It should be mentioned that the bandstop filters were slightly tuned. As can be seen, an excellent performance was achieved. The insertion loss from the antenna to Rx ports was less than 0.3 dB over the desired Rx sub-band (15 MHz). The insertion loss from the Tx port to antenna port was also less than 0.3 dB across the whole Tx band (75 MHz). The isolation between the Tx and Rx ports was larger than 35 dB over the Tx band. A very good match was also obtained at all ports. A summary of the measurement performance is given in Table I.

The above test results were obtained at the Rx power level (0 dBm). The operational transmitter output power is typically 12 W. However, tests conducted at the highest power available to us (8 W) showed an increase in insertion loss between the transmitter to antenna ports of about 0.45 dB.

V. DUPLEXER/ENCAPSULATION ASSEMBLY

Shown in Fig. 11 is a photograph of three similarly fabricated HTS duplexers assembled in an RF connector ring for encapsulation [8]. Conventionally the cryogenic/RF interconnection across the encapsulation vacuum space is accomplished using high thermal resistance lossy coaxial cables. In this design, a microstrip feed network and a novel RF/thermal link were used to achieve a low conduction heat load. The RF signals are propagated from the ambient temperature side to the cold side through short thin bond wires. The whole RF connector ring with a tuning lid was cooled down to a temperature of 55 K in a vacuum cooler. The measurements were taken at ports of the RF connector ring. Fig. 12 shows a set of typical measured results, and Table II summarizes the measured performance. In general, good performance has been achieved though the measured insertion losses and return losses were higher than those of the HTS duplexer tested in the test housing. In this case, the maximum insertion loss from the antenna port to the receiver port was 1.13 dB, while the maximum insertion loss from the transmitter to antenna ports was 1.15 dB. These figures are consistent with the losses and mismatch of the non-HTS microstrip circuits.

VI. CONCLUSION

We have presented recent investigations carried out on an HTS duplexer for cellular base-station applications. The duplexer consists of two HTS hybrids and two HTS bandstop filters. The principle and design of the duplexer have been described. The design has been performed with the aid of a full-wave EM simulator. The components of the duplexer have been fabricated using double-sided YBCO thin films on LAO substrates. The substrate sizes for each of the HTS hybrids and each of the HTS bandstop filters are 0.5 × 22.5 × 15.5 mm and 0.5 × 13× 38 mm, respectively. We have conducted the measurements on the duplexer both in a test housing and in the RF connector ring of a vacuum encapsulation. The comparison of the two sets of measured results indicates that the major challenges in the applications of HTS to communication systems are not just HTS components alone, but also the associated components in the implementation of the vacuum encapsulation. Nevertheless, very good performance has been measured, showing that the HTS duplexer holds promise for cellular base-station applications.

ACKNOWLEDGMENT

The authors would like to thank D. C. Voyce, G. Pells, R. Mistry, H. U. Häfner, G. Auger, and other colleagues, all of whom have contributed to this paper.

REFERENCES

[1] D. Reeder, "A cryogenic option for expanding coverage," in *Mobile Commun. Int. Conf.*, June 1996, p. 57.

[2] STI Inc., "A receiver front end for wireless base stations," *Microwave J.*, vol. 39, no. 4, p. 116, 1996.

[3] R. B. Hammond, "HTS wireless filters," *Microwave J.*, vol. 41, no. 10, pp. 94–107, 1998.

[4] M. J. Lancaster, *Passive Microwave Device Applications of Superconductors*. Cambridge, U.K.: Cambridge Univ. Press, 1997.

[5] S. H. Talisa, M. A. Robertson, B. J. Meler, and J. E. Sluz, "Dynamic range considerations for high-temperature superconducting filter applications to receive front ends," in *IEEE MTT-S Microwave Int. Symp. Dig.*, 1997, pp. 997–1000.

[6] G. Koepf, "Superconductors improve coverage in wireless networks," *Microwave RF*, vol. 37, no. 4, pp. 63–72, Apr. 1998.

[7] Y. Vourc'h, G. Auger, H. J. Chaplopka, and D. Jedamzik, "Architecture of future basestations using high temperature superconductors," in *ACTS Mobile Summit*, Aalbourg, Denmark, Sept. 1997, pp. 802–807.

[8] R. B. Greed, D. C. Voyce, J.-S. Hong, M. J. Lancaster, M. Reppel, H. J. Chaloupka, J. C. Mage, R. Mistry, H. U. Häfner, G. Auger, and W. Rebernak, "An HTS transceiver for third generation mobile communications—European UMTS," in *IEEE MTT-S European Wireless Symp. Dig.*, 1998, pp. 98–103.

[9] M. Muraguchi, T. Yukitake, and Y. Naito, "Optimum design of 3-dB branch-line couplers using microstrip lines," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-31, pp. 674–678, Aug. 1983.

[10] T. Hirota, A. Minakawa, and M. Muraguchi, "Reduced-size branch-line and rat-race hybrids for uniplanar MMIC's," *IEEE Trans. Microwave Theory Tech.*, vol. 38, pp. 270–275, Mar. 1990.

[11] I. Sakagami, T. Munehiro, H. Tanaka, and T. Itoh, "Branch-line hybrid-rings with coupled-lines," in *Proc. European Microwave Conf.*, 1994, pp. 686–691.

[12] J. P. Shelton, J. Wolfe, and R. C. Van Wagoner, "Tandem couplers and phase shifters for multi-octave bandwidth," *Microwaves*, pp. 14–19, Apr. 1965.

[13] "EM User's Manual," Sonnet Software Inc., Liverpool, NY, Ver. 2.4, 1993.

[14] G. L. Matthaei, L. Young, and E. M. T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures*. Norwood, MA: Artech House, 1980, ch. 12.

Jia-Sheng Hong (M'94) received the D.Phil. degree in engineering science from Oxford University, Oxford, U.K., in 1994.

From 1979 to 1983, he was a Teaching and Research Assistant of radio engineering with Fuzhou University. He then visited Karlsruhe University, where, from 1984 to 1985, he was involved with microwave and millimeter-wave techniques. In 1986, he returned to Fuzhou University, as a Lecturer in microwave communications. In 1990, he became a Graduate Member of St. Peter's College, Oxford University, where he conducted research in EM theory and applications. Since 1994, he has been a Research Fellow at Birmingham University, Birmingham, U.K. His current interests include RF and microwave devices for communications, microwave filters and antennas, microwave applications of high-temperature superconductors, EM modeling, and circuit optimization.

Dr. Hong was the 1983 recipient of a Friedrich Ebert Scholarship and the 1990 recipient of the K. C. Wong Scholarship presented by Oxford University.

Michael J. Lancaster (M'91) received the physics degree and the Ph.D. degree in nonlinear underwater acoustics from Bath University, Bath, U.K., in 1980 and 1984, respectively.

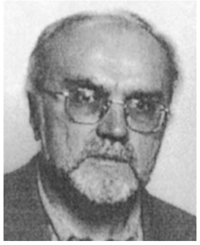
Upon leaving Bath University, he joined the Surface Acoustic Wave (SAW) Group, Department of Engineering Science, Oxford University, Oxford, U.K., as a Research Fellow, where he was involved in research of the design of new novel SAW devices, including filters and filter banks. These devices worked in the frequency range of 10 MHz–1 GHz. In 1987, he became a Lecturer in the School of Electronic and Electrical Engineering, University of Birmingham, Birmingham, U.K., where he teaches EM theory and microwave engineering. Shortly after joining the School of Electronic and Electrical Engineering, he began the study of the science and applications of high-temperature superconductors, involved mainly with microwave frequencies. He currently heads the Electronic and Materials Devices Group as a Reader. His current personal research interests include microwave filters and antennas, as well as the high-frequency properties and applications of a number of novel and diverse materials.

Dr. Lancaster is currently serving on the IEEE Microwave Theory and Techniques Society (IEEE MTT-S) International Microwave Symposium Technical Committee.

Robert B. Greed, photograph and biography not available at time of publication.

Dieter Jedamzik, photograph and biography not available at time of publication.

Jean-Claude Mage (A'85), photograph and biography not available at time of publication.



Heinz J. Chaloupka (S'68–M'69–SM'00) received the Dipl.-Ing. (M.Sc.) degree from the Technical University of Darmstadt, Darmstadt, Germany, in 1969, and the Dr.-Ing. (Ph.D.) degree in electrical engineering from the University of Bochum, Bochum, Germany, in 1975.

From 1969 to 1975, he was a Research Assistant at the University of Bochum, where he was involved with EM theory and numerical methods for solving field problems. From 1976 to 1983, he was a Senior Research Engineer conducting research on direct and inverse scattering problems, imaging with EM waves with synthetic aperture methods, and industrial applications of microwave techniques. Since 1983, he has been a Professor of microwave techniques at University of Wuppertal, Wuppertal, Germany. His current research activities include microwave system applications of HTS's in field communication and sensing, as well as the theory and practical realization aspects of small arrays with adaptive beamforming capabilities. In the field of microwave superconductivity applications, he is cooperating with the spin-off company Cryoelectra GmbH, Wuppertal, Germany, which provides cryogenic microwave components and subsystems for mobile communication base-stations and navigation systems.

Dr. Chaloupka is a senior member of the IEEE Microwave Theory and Techniques Society (IEEE MTT-S) 18 Committee on Microwave Superconductor Applications.